DOE SNF Canister Survivability Report

National Spent Nuclear Fuel Program

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Providing for safe, efficient disposition of DOE spent nuclear fuel

Scope of the Survivability Report

- Addresses Standardized Canisters <u>and</u> MCOs
- Addresses credible preclosure drop events
- Considers the following canister conditions:
  – As-designed
  – Material and fabrication flaws
    - base metal flaws
    - weld flaws
  – Age-related degradation

Evaluation of As-Designed DOE SNF Canisters

- DOE SNF canisters are designed and fabricated to ASME B&PV Code Section III.
- Localized canister deformations due to drop events will likely exceed ASME Code.
- ISG-10 provides for alternatives to the ASME Code when requirements are determined to be not applicable or impractical.
- A combination of analyses and tests demonstrate survivability.

Structural Response Analyses

- Canister drops were modeled with ABAQUS/Explicit and validated by testing
  - 18-in. standardized canisters drop tests conducted in 1999
  - The 24-in. standardized canister and MCO drop tests conducted in 2004
- Results indicate that radionuclide containment will be maintained for all credible drop events.

Conclusions for As-Designed Condition

- Canisters are designed, fabricated, and N-stamped to ASME Code requirements.
- Analyses show a significant margin to failure.
- Drop tests validate the analytical model and demonstrate containment integrity.

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Evaluation of Flawed Canisters

- Base metal flaws are considered bounded by weld flaws.
- For final closure welds as confinement boundaries on stainless steel canisters, ISG-18 states that reasonable assurance of no leakage is achieved by using welding and examination techniques described by ISG-15.
- DOE SNF canister weld design, specifications, and tests are consistent with ISG-15.
- According to ISG-15, the minimum detectable flaw size must be demonstrated to be less than the critical flaw size.

Testing Confirmed Critical Flaw Size Greater than Detection Threshold

- Flaws 150% of the detection limit (i.e., 1.5 mm flaw) did not result in through-wall cracking.
- Flaws up to a single weld pass (about 2.5 mm) did not result in through-wall cracking.

Additional Considerations for Weld Flaws

- All but the closure welds are made and inspected at the fabrication facility to ASME Code requirements and independently reviewed by an authorized inspector.
- Closure welds for the standardized canister are not near highest strain.
- MCOs have a mechanical seal inside of the closure weld providing an additional barrier against release.

Age-Related Degradation

Degradation mechanisms considered include:

- Electrochemical interactions, such as general corrosion, pitting corrosion, and SCC
- Mechanical forces such as overpressurization
- Metallurgical degradation such as hydrogen embrittlement, liquid metal embrittlement
- Thermal effects due to welding.

Conclusion for Age-Related Degradation

- Degradation is minimal even without complete drying because of the stainless steel materials.
- Drying, inerting, and verification of dryness prevent degradation.
- The probability of failing to properly dry a canister is $\leq 2.3 \times 10^{-4}$.

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Summary and Conclusion

- Canisters are designed, fabricated, and tested per ASME Code.
- Analytical modeling and testing confirm canister survives maximum credible drops.
- Testing demonstrates that undetectable (i.e. uncorrected) flaws will not result in crack growth.
- NRC ISG-15 provides confidence the approach will be accepted by the NRC.
- Failure to properly dry canister contents is considered the dominant failure mode.
- Conditional probability of canister breach given a drop is $<2.3 \times 10^{-4}$.